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NAVAL AIR TEST CENTER TECHNICAL REPORT

REPORT NO. 1, FINAL REPORT

HELICOPTER STATIC DISCHARGING

by

Mr. C. R. Stott

DDC
MAY 25 1965
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NAVAL AIR TEST CENTER
U. S. NAVAL AIR STATION
Patuxent River, Maryland 20670

RAE50P023
023-AE54-14/A
WST33-22R-65
26 Apr 1965

From: Commander, Naval Air Test Center
To: Chief, Bureau of Naval Weapons

Subj: NATC Technical Report WST33-22R-65, Helicopter Static Discharging, Report No. 1, Final Report; transmittal of

Ref: (a) WEPTASK Assignment RAE50P023/2011/F012 07 01 Amendment 2 of 18 Jul 1963
(b) BuWeps Problem Assignment 023-AE54-14 of of 8 Nov 1963
(c) BuWeps ltr RAAE-541/55:SLW of 27 Nov 1963
(d) BuWeps Problem Assignment 023-AE54-14, Amendment A of 2 Apr 1964

1. Reference (a) authorized the test, investigation, installation, and evaluation of aircraft electrical systems and components for power generation, distribution, and lighting. Reference (b) requested an evaluation of the methods to discharge static electricity from helicopters. Reference (c) extended the evaluation to include the preproduction Dynasciences Model DO-3 discharger system. Reference (d) cancelled and superseded references (b) and (c) and requested an evaluation of helicopter static electricity dischargers.

2. This report completes the problem assignment.

JAMES R. LEE

E. H. DOOLIN, JR.
By direction

WST33-22R-65

NAVAL AIR TEST CENTER
U. S. NAVAL AIR STATION
Patuxent River, Maryland 20670

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ABSTRACT

[illegible]

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INTRODUCTION

BACKGROUND

1. Helicopters in flight or hover accumulate a charge of static electricity from the motion of the rotor(s) through the air, the release of ions in the engine's exhaust gases, or by flying through large variations in the earth's electrical field. The discharge of this static electricity could cause harm to personnel or ignite fuel. This project was established to evaluate the effectiveness of static dischargers and to determine the discharge capacity required for the UH-2A helicopter.

2. Natural discharge of static electricity occurs at any sharp point on an aircraft. As the static voltage on the aircraft increases, the air around the sharp point ionizes and an electric current flows between the ionized air and the sharp point. This current flow reduces the static voltage of the aircraft and thus is called discharge current. As the voltage of the sharp point increases, the discharge current increases. To complete the phenomenon, a flow of air across the sharp point must exist.

3. The threshold of human feeling is defined as the minimum energy level at which a person can sense an electrical shock from a static voltage. Reference 1 reported that the threshold of human feeling is one millijoule. Any energy levels above this value can be felt by personnel, and, if high enough, can cause a dangerous shock.

PURPOSE

4. The purpose of this report is to present the results of the evaluation.

DESCRIPTION OF EQUIPMENT

5. The Dynasciences Corporation of Fort Washington, Pennsylvania, loaned a Model DO-3 static discharger system for the evaluation. It consists of one each of the following units: sensor, positive exciter, positive multiplier, negative exciter, negative multiplier, cockpit control and cargo control. The size and weights of the individual units are shown in table I.

Table I

Size and Weight Measurements of the
Dynasciences Model DO-3 Discharger System

Quantity	Item	P/N	Shape	Size* (in.)	Weight (lb)	Figures
1	Sensor	LV02	Cylinder	5.0 H 5.0 D	1.75	1-2-3
2	Exciter	HE01 HE02	Rectangular solid	11.0 L 7.0 H 5.0 W	6.95 7.00	5
2	Multiplier	HM01 HM02	Rectangular solid	20.0 L 2.0 H 10.0 W	6.90 7.50	1-4
1	Cockpit Control	CP01	Rectangular solid	2.5 L 2.0 H 2.0 W	0.30	6
1	Cargo Control	CC01	Rectangular solid	4.0 L 2.5 H 2.5 W	0.90	6
1	Probe & Wick		Circular tube	28.4 L 0.5 D	0.20	1
1	Probe & Wick		Circular tube	6.9 L 0.5 D	0.20	4
			Total Weight -		31.70 lb	

*These measurements are exclusive of the connecting plugs.
L = Length, H = Height, W = Width, D = Diameter

6. The input requirements of the discharger system are: 115 v, 370 to 430 cps with a 24 volt-amperes load and a

power factor of 0.15 lag, and 28 vdc with a load varying from 3 to 60 watts. The output capacity of the system is a discharging current of 150 microamperes. The dc circuits will operate satisfactorily with a ripple voltage as high as eight volts.

7. The Dynasciences Model DO-3 discharger system causes a discharge of static electricity from an aircraft similar to the natural discharge from a sharp point. In this system, the sharp point consists of a wick on the end of each probe. Through the action of an exciter and a multiplier, a high voltage, which is many times that of the aircraft, is applied between the aircraft and the wick. The sensor determines the polarity and magnitude of the static voltage of the aircraft, and controls the voltage and voltage polarity of the respective discharge wick to neutralize the static voltage on the aircraft.

8. The locations of the sensor and the high voltage multipliers on the helicopter are critical. The sensor must be located so that discharges from the wicks do not affect it, and in a position which will give a satisfactory voltage indication. Installation of the multipliers must be such that the discharge wicks are in a region of high rotor downwash air. Each high voltage unit consists of two parts: an exciter which is mounted inside the aircraft and a multiplier, which is mounted outside the aircraft. The two parts are bolted together with the aircraft skin between them. Two control units are provided, each equipped with two lights to indicate the safe or unsafe operation of the discharger system.

9. The UH-2A helicopter, BuNo 147979, was used for this evaluation and weighs approximately 10,150 pounds.

SCOPE OF TESTS

10. Tests were conducted to evaluate the model DO-3 discharger system, to measure the helicopter static voltage and charging current and to determine the feasibility of discharging the static electricity. Tests were made under summer conditions when available charging current was low.

11. Qualification tests were not conducted on the discharger system. The Dynasciences Corporation reported in reference 4 that the system had been evaluated in accordance with specification MIL-E-5272C.

INSTALLATION

12. Figure 1 shows the sensor mounted at station 48 on the helicopter. Close-up views of the sensor are shown in figures 2 and 3.

13. The location of the positive multiplier is also shown in figure 1. Figures 4 and 5 show the negative multiplier and exciter. All exciters and multipliers were installed at station 398.6.

14. Figure 6 shows the cockpit control unit and the cargo control unit, which were mounted at station 199.4 (cargo compartment) in the helicopter.

METHOD OF TESTS

15. The static voltage and charging current on the UH-2A helicopter were measured with the helicopter hovering at an altitude between five and ten feet. The helicopter static voltage and charging current were measured by connecting a high-resistance voltmeter and a microammeter, respectively, between the skin of tne helicopter and earth ground. A tabulation of the test instrumentation is given in Appendix II.

16. Additional information was collected at conferences and reviewed with personnel from Dynasciences Corporation, Fort Washington, Pennsylvania, and the Transportation Research Command (TCREC), Fort Eustis, Virginia.

Figure 1
UH-2A Helicopter with Dynasciences
Model DO-3 Discharger System Installed

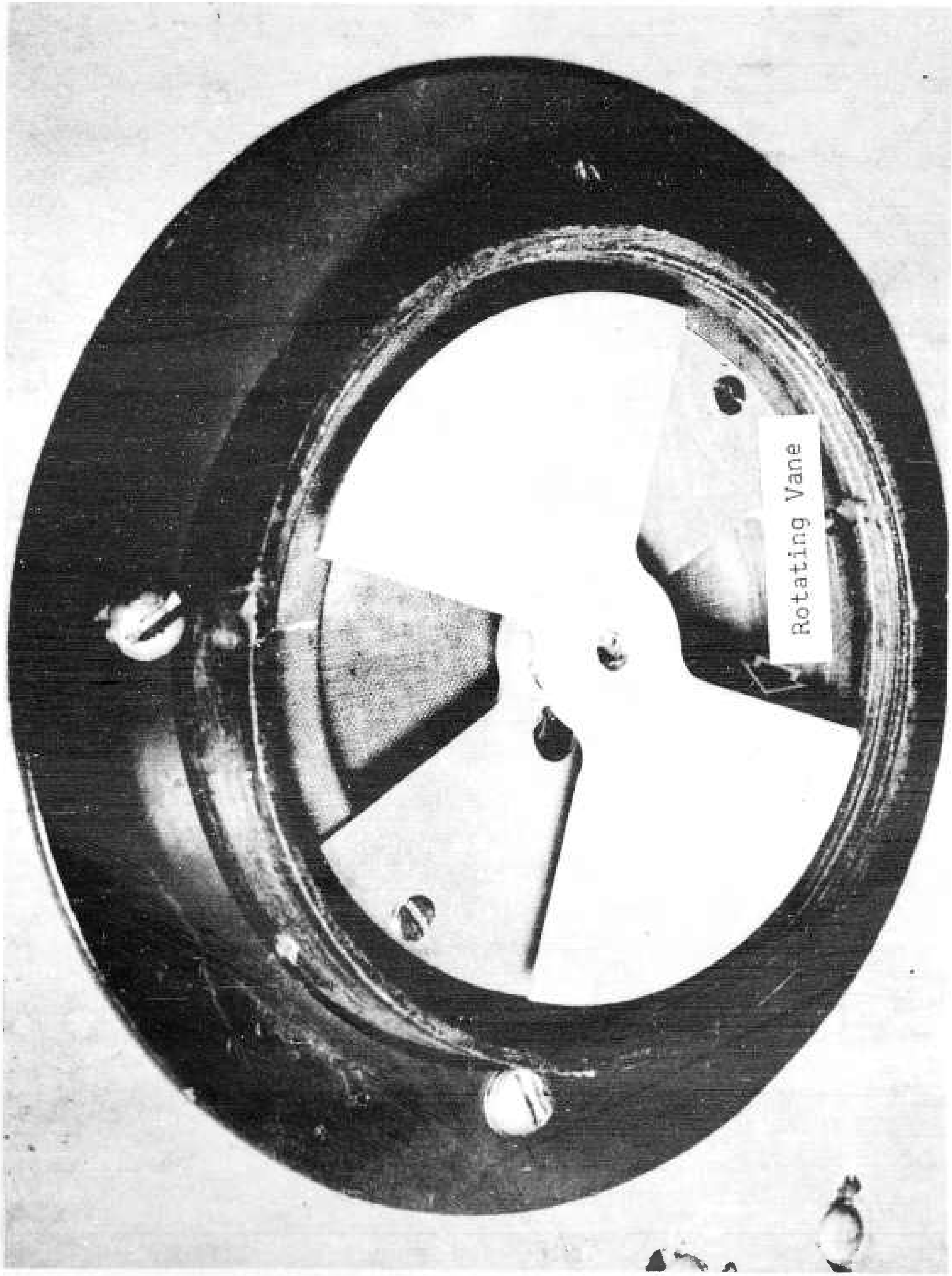


Figure 2
Portion of the Sensor Located Outside of the Helicopter

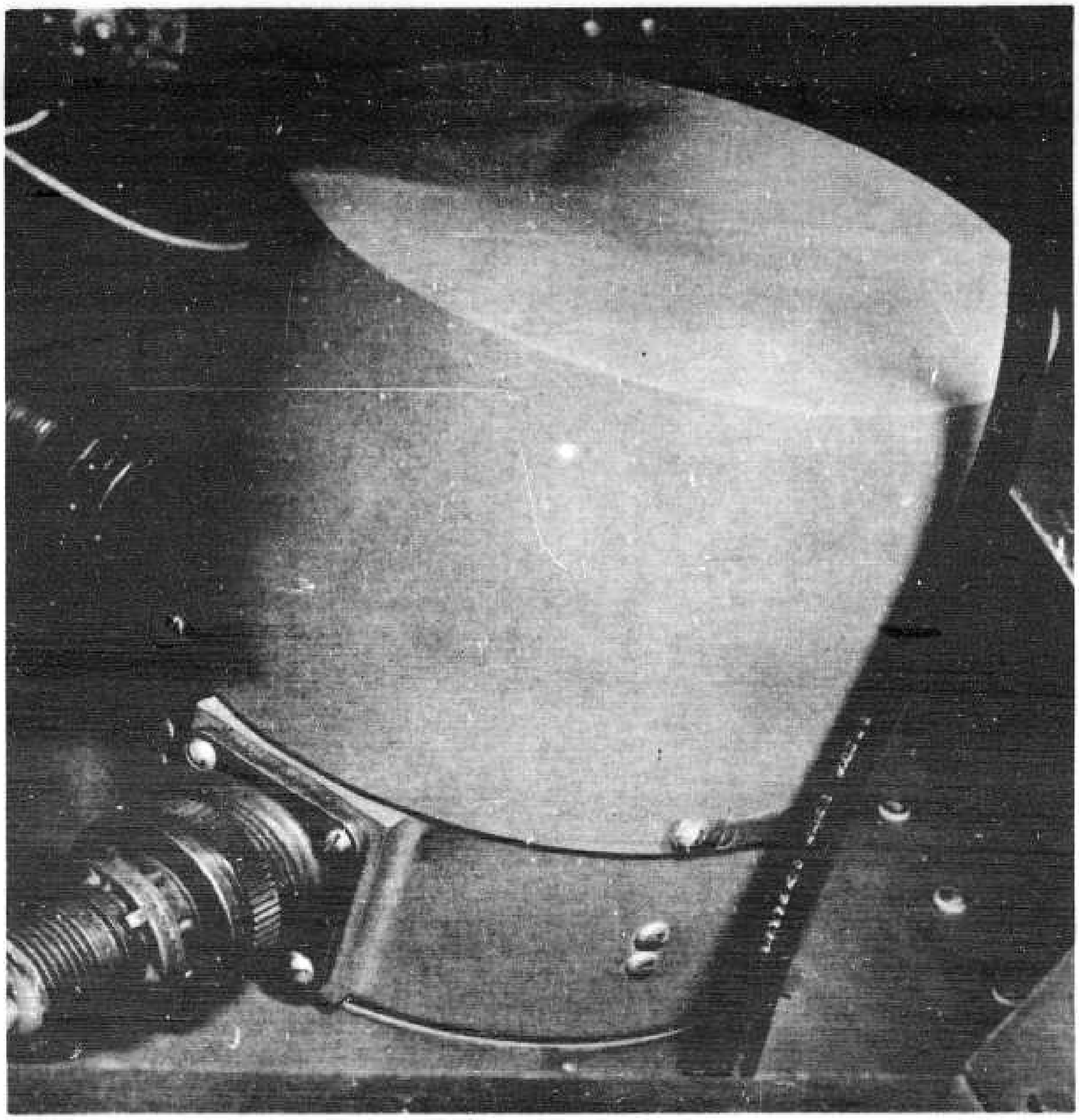


Figure 3
Portion of the Sensor Located
Inside the Helicopter

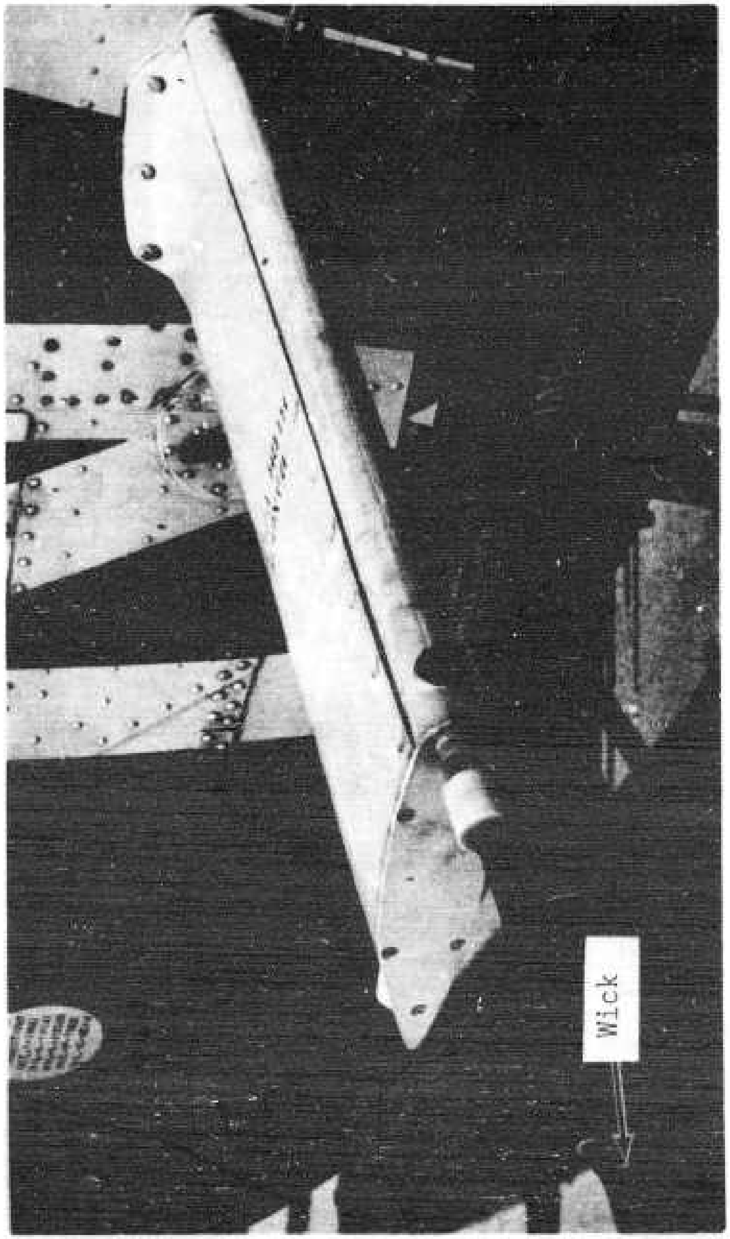


Figure 4
Negative Multiplier Unit

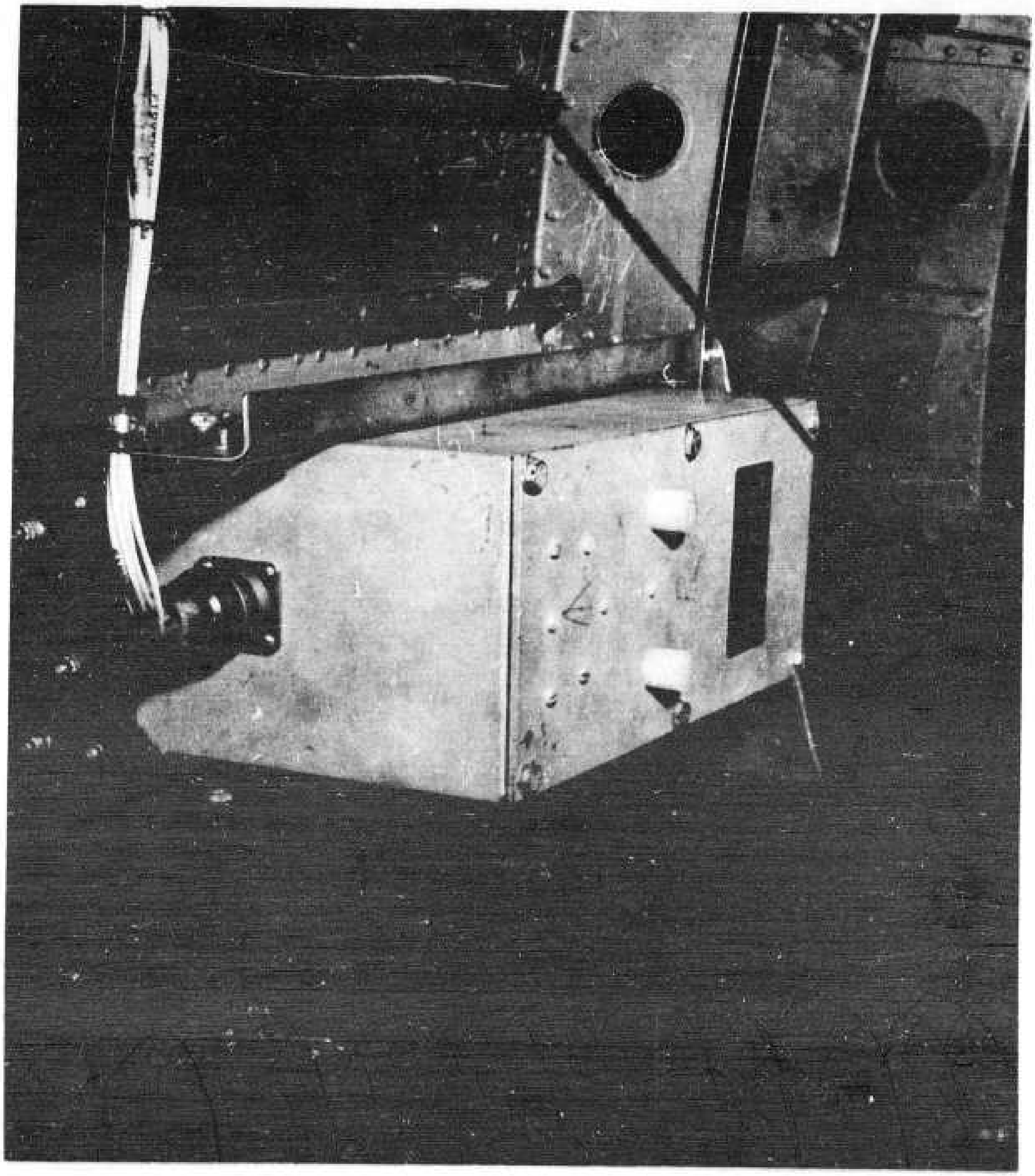
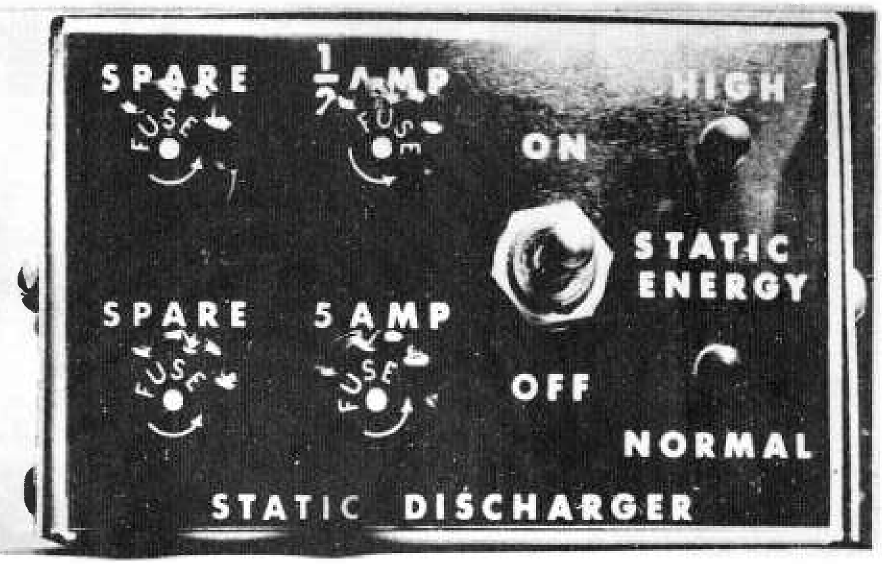


Figure 5
Negative Exciter Unit

Cockpit Control Unit



Cargo Control Unit

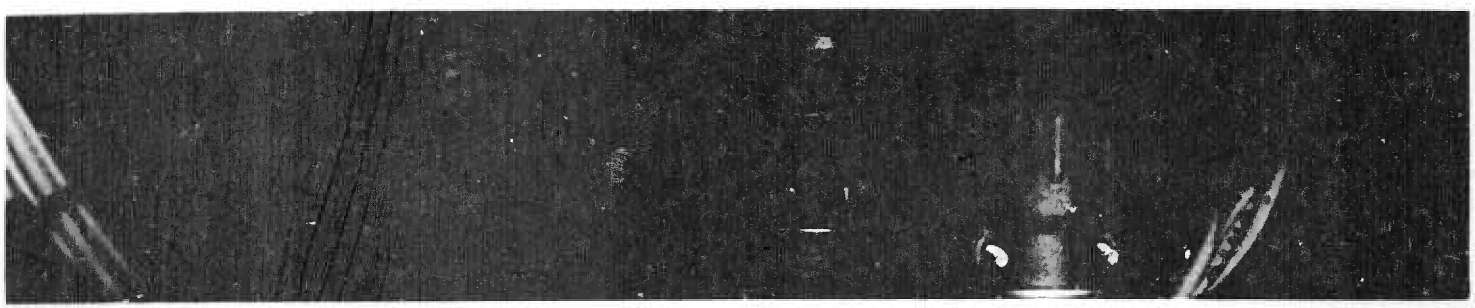


Figure 6
Cockpit Control Unit and Cargo Control Unit

RESULTS AND DISCUSSSION

17. The vanes of the sensor are exposed. The rotation of the top vane could result in injury to ground personnel and possible jamming by foreign particles during flight. It would be advisable to redesign the sensor to give protection. However, the manufacturer states that the open vane arrangement is necessary for the proper operation of the discharger system. Any shielding around the sensor would interfere with the function of the sensor.

18. The threshold of human feeling was calculated for the UH-2A helicopter. In reference 2, the Dynasciences Corporation reported that the capacitance (C) of a UH-2A helicopter is approximately 500 picofarads. By using the equation

$$V = \sqrt{\frac{2W}{C}} = \sqrt{\frac{2 \times 10^{-3}}{500 \times 10^{-12}}} = 2 \times 10^{3} \text{ volts}$$

where V = volts, W = energy in joules (one millijoule for this calculation), C = capacitance in farads, the voltage for the threshold of human feeling for the UH-2A is calculated to be two kilovolts. This voltage is a factor to be considered in the design of the discharger system to protect personnel.

19. During tests of the failure detector, the maximum helicopter static voltage at which the warning lights indicated a safe condition (green light on and red light off) was four kilovolts. This voltage is higher than the two-kilovolt value for the threshold of human feeling but should not cause a harmful shock. However, it is desirable for the failure detector lights to be adjusted for the two-kilovolt threshold voltage of the helicopter in which the discharger system is installed.

Discharge Current Capacity and Recirculating Current

20. To determine the discharge current capacity and maximum recirculating current of the discharger system, the probe current must be a maximum. A maximum probe current is obtained by saturating the sensor. A test plate is placed in

front of the sensor vanes, and a voltage to represent a helicopter static voltage of 1700 volts or higher is applied to the test plate. The polarity of the potential determines which high voltage exciter and multiplier will operate. With the sensor saturated, the discharge current capacity and the recirculating current are determined by measuring the charging current (I_c), the probe current (I_p), and the ground current (I_g). The discharge current capacity (I_o) of the system is the sum of the charging current and the ground current.

$$I_o = I_c + I_g$$

The recirculating current (I_r) reduces the effect of the probe current and can be calculated by use of the following equation:

$$I_r = I_p - (I_c + I_g)$$

Because of the effect of the recirculating current on the probe current, the discharge current capacity is reduced. A relationship between the two currents is:

$$I_o = I_p - I_r$$

Therefore, the recirculating current directly affects the discharge current capacity and should be kept at a minimum value.

21. Two flights were made to determine the discharge current capacity of the discharger system. The expected maximum charging current for the UH-2A helicopter, as reported in reference 2, is approximately 30 microamperes. The results of the NATC tests summarized in table II show that the absolute discharge current capacity of the discharger system is greater than (>) 50 microamperes and less than (<) 75 microamperes, and that the absolute value of the recirculating current was less than 25 microamperes. Therefore, the discharge current capacity of the model DO-3 discharger system is adequate.

Table II

Discharge Current Capacity of Dynasciences
Model DO-3 Discharger System
(All Currents in Microamperes)

		Positive Helicopter Static Charge			Negative Helicopter Static Charge			
Flight	I_c	I_g	I_p	I_r	I_g	I_p	I_r	I_o
A	+1.0	>+50	-74	<-23	>-50	+75	<+26	>±50
B	+1.0	>+50	-74	<-23	>-50	+75	<+26	>±50

22. The discharger system was designed for a maximum probe current of 150 microamperes. The maximum probe current listed in table II was 75 microamperes. Dynasciences personnel reported that the probe current of the system could have been increased to 150 microamperes by making adjustments to the sensor circuits, but this was not considered necessary for test purposes, as the expected requirements of the UH-2A helicopter are met by the present system. With a probe current of 150 microamperes, the discharger system would have a discharge current capacity greater than 100 microamperes. In a redesign, a reduction in discharge current capacity to that required for the UH-2A would result in a desirable reduction of weight and size.

23. The negative high voltage probe was shortened so that the outer extremity of the wick was 35.9 in. from the helicopter skin instead of the previous 57.4 in. The positive high voltage probe was left at its original length. The shortened probe caused no apparent effect on the electrical measurements.

24. Figure 7 is a recorded trace which shows the results of operation of the discharger system before and after the system is energized. The sensor voltage was calibrated so that a direct readout for sensored voltage could be made. Prior to the discharger system being energized, the helicopter static voltage was measured to be 20,000 volts, the maximum helicopter static voltage measured during the evaluation. The recorded trace indicates 1700 volts, the saturation voltage of the sensor. When the system was energized, the sensored voltage was reduced to and remained between 0 and -800 volts. This voltage is below the threshold of human feeling and thus affords personnel protection from electrical shock. The time required to reduce the voltage from 20 kilovolts to a safe level was less than 0.5 sec

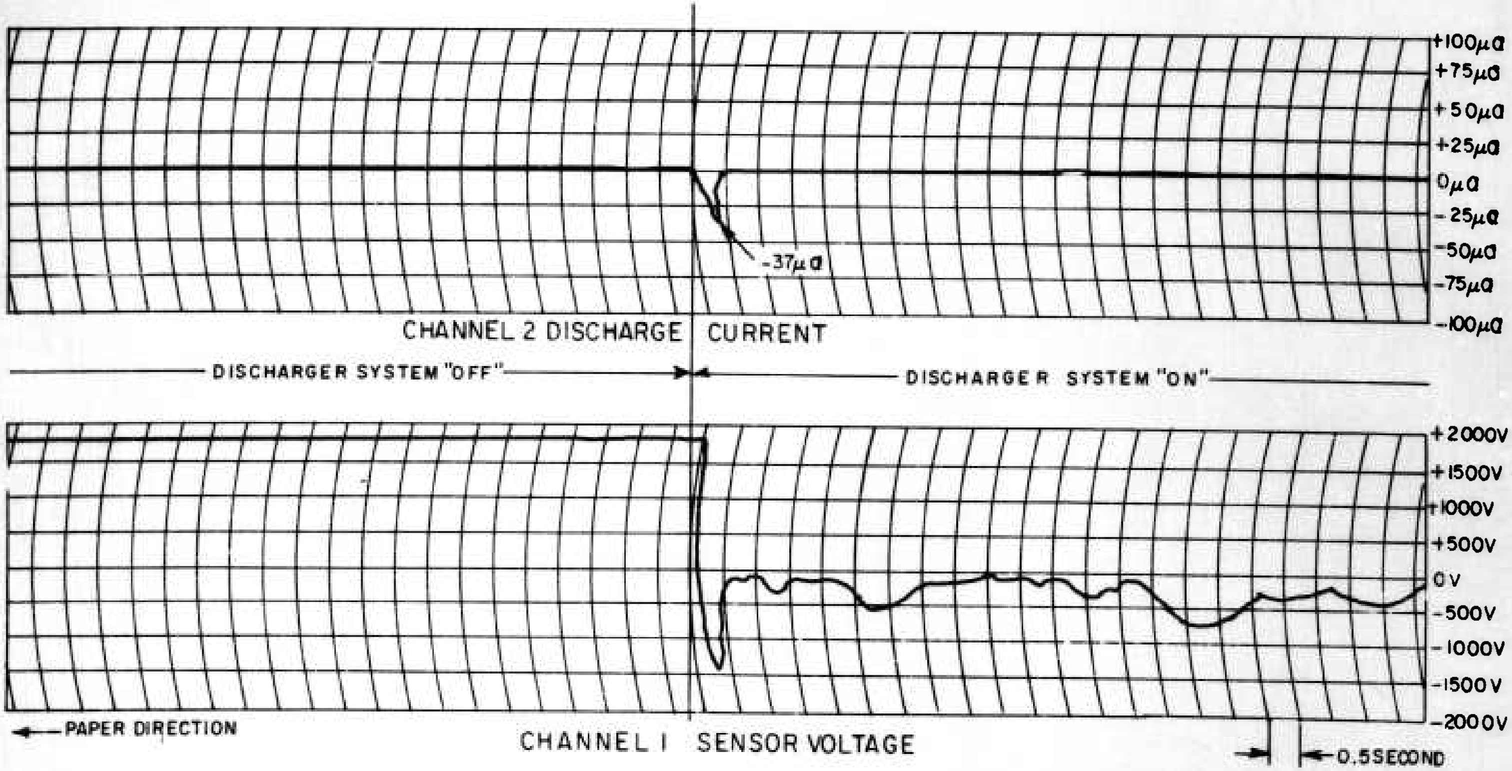


Figure 7
Recorder Trace Showing Results Obtained During the Operation of the Model DO-3 Discharger System

and required a transient discharging current of -37 microamperes. The steady state discharging current was too small to discern on the recorder trace but should be equal to the charging current, which was two microamperes.

25. The model DO-3 discharger system, as tested, did not include a relay to turn off the high voltage multiplier outputs while the helicopter was on the ground. This cutoff feature is required to protect the ground personnel from the high voltage (as high as 200,000 volts) on the discharge wicks. It is mandatory that a relay or other means be included in the discharger system to protect ground personnel.

26. Table III is a condensation of a table given in reference 3 and is presented to illustrate that very high static voltages of both positive and negative polarity can be experienced on helicopters. The Dynasciences Corporation reported that voltages have been experienced on helicopters in excess of one million volts. Voltages of this magnitude were not experienced during NATC tests because of high humidity conditions which existed at Patuxent River, Maryland, during the summer months.

Table III

Helicopter Static Voltages and Charging Currents Measured on the CH-37B (H-37B) Helicopter

Max. Volts & Polarity	Current (microamperes)
- 50,000	5 to 11.0
-200,000	45 to 50.0
+ 60,000	1 to 1.5
+ 55,000	3

CONCLUSIONS

27. The maximum charging current measured on the UH-2A helicopter was one microampere. The estimated maximum charging current is 30 microamperes (paragraph 21).

28. The maximum helicopter static voltage measured during the tests was 20,000 volts and was reduced to a safe level of 0 to -800 volts by the DO-3 discharger system (paragraph 24).

29. Results of the flight evaluation verified that the Dynasciences model DO-3 discharger system is effective in discharging static electricity from the UH-2A helicopter (paragraph 24).

30. Redesign of the Dynasciences model DO-3 discharger system should be made to correct the following deficiencies:

a. Inclusion of relay or other means in the discharger system to protect ground personnel from the high voltages on the discharge wicks is mandatory (paragraph 25).

b. The discharging current capacity, weight and size are larger than necessary for the UH-2A helicopter (paragraph 22).

c. The operating point of the failure detector circuit is higher than the two-kilovolt threshold of human feeling for the UH-2A helicopter (paragraph 19).

d. The distance that the discharge probes extend from the helicopter is greater than needed (paragraph 23).

e. The open and exposed rotating vanes of the sensor endanger ground personnel (paragraph 17).

RECOMMENDATIONS

31. Accept the principle of operation of the Dynasciences Model DO-3 discharger system as an effective means to discharge static electricity from the UH-2A helicopter.

32. Redesign the Dynasciences Model DO-3 discharger system to correct deficiencies and increase its adaptability to the UH-2A helicopter.

33. Further test and evaluation of an improved design of the Dynasciences Model DO-3 discharger system should be performed.

REFERENCES

1. Helicopter Static Electricity Discharging Device, TCREC Technical Report 62-33 of December 1962.

2. NATC Flight Tests of Model DO-3 Aircraft Electrostatic Discharger System, Test Report by Dr. Juan de la Cierva of 27 August 1964.

3. Helicopter Static-Electricity Measurements, TCREC Technical Report 62-72 of June 1962.

4. Dynasciences Corporation letter DC-2085-C222 of 2 November 1964.

INSTRUMENTATION USED IN THE FLIGHT TESTS OF THE DYNASCIENCES MODEL DO-3 DISCHARGER SYSTEM

Equipment	Use
Electrostatic Discharger Test Set*	To measure discharging current, probe current, ground current, and sensor voltage
Brush Recorder*, Mark II Model RD 2522-00, Serial No. 289	To measure charging current, probe current, ground current, and sensor voltage
Keithley Electrometer, Model 210, Serial No. 184	To measure helicopter static voltage
Keithley Voltage Divider, Part No. PA51419-34	To measure helicopter static voltage
Field Test Plate*, Part No. TP02, Serial No. 101	To determine capacity of discharger system
Leland 750 VA Inverter, Part No. SE-7-1, Serial No. SA-6735	To supply 60 cps power to Electrometer and Brush Recorder
National Carbon 500 Volt Battery*	To calibrate Brush Recorder

NOTE: All test instrumentation was located at station 199.4 (cargo compartment) in the UH-2A helicopter.

*Furnished by the Dynasciences Corporation

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(NATC TECHNICAL REPORT WST33-22R-65)

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Helicopters in flight or hover accumulate a charge of static electricity which, when discharged, could cause harm to personnel or ignite fuel. The project was established to study the charge and discharge characteristics of static electricity on the UH-2A helicopter and to evaluate the preproduction Dynasciences model DO-3 discharger system. Flight tests were conducted during summer conditions when the available charging current and helicopter static voltages were low. The maximum charging current measured on the UH-2A helicopter was one microampere. The discharger system reduced a 20-kilovolt helicopter static voltage to a level between 0 to -800 volts in 0.5 second. The predicted maximum charging current for the UH-2A helicopter is 30 microamperes. The Dynasciences model DO-3 discharger system provides an effective means to discharge static electricity from the UH-2A helicopter. Recommendations are made for redesign to adapt the discharger system to the UH-2A helicopter.

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